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Reviews.

A Treatise on Metamorphism. By Charles Richard Van Hise. (Monograph XLVII, U. S. Geological Survey.) Washington, D. C. Pp. 1,286; 13 plates. $1.50.

This treatise is an attempt to reduce the phenomena of metamorphism to order under the principles of physics and chemistry, or, more simply, under the laws of energy. Metamorphism is broadly defined to include all alterations of all rocks by all processes. The metamorphism of the sedimentary rocks was the first subject studied by the author, and metamorphism has been a chief line of investigation with him for more than twenty years. Finding that the alteration of rocks was nowhere systematically treated, he took up the task of preparing such a work. It was supposed that this work would occupy two or three years, but, as a matter of fact, it required seven years, and an eighth year has been needed to put the volume through the press.

The book consists of twelve chapters. Chapter 1 discusses the geological principles upon which a classification of metamorphism may be based. From this discussion it is concluded that the only practicable classification of metamorphism is geological. It is found that the alterations of the outer zone of the earth are radically different from those of the deep-seated zone. Moreover, it is shown that the alterations in the upper zone result in the production of simpler compounds from more complex ones, while those in the deep-seated zone result in the production of complex compounds from more simple ones. The upper zone is called that of katamorphism, and the lower zone that of anamorphism.

Chap. 2, upon the forces of metamorphism, discusses chemical energy, gravity, heat, and light. The manner in which each of the classes of energy produces various mechanical and chemical effects upon rocks is set forth.

Chap. 3 treats of the agents of metamorphism. The agents of metamorphism are gaseous solutions, aqueous solutions, and organisms. Under aqueous solutions the chemical and physical principles controlling the action of ground water and the circulation of ground water are fully discussed. This involves a full résumé of the science of physical chemistry, so far as applicable to the alterations of rocks. This résumé is not simply a summary

from textbooks of physical chemistry, but discusses the applications of the principles to the phenomena of metamorphism.

Chap. 4, upon the zones and belts of metamorphism, discusses these zones and belts from the physical-chemical point of view. It is shown that the alterations of the zone of katamorphism occur with liberation of heat and expansion of volume, the chief reactions being oxidation, carbonation, and hydration. The alterations of the zone of anamorphism occur with absorption of heat and diminution of volume, the chief reactions being deoxidation, silication with decarbonation, and dehydration. Thus the alterations in the two oppose each other. The zone of katamorphism is divided into two belts—that above the level of ground water, the belt of weathering, and that below the level of ground water, called the belt of cementation. While the physical-chemical principles of alteration are the same in each of these belts, the geological processes are very different. The belt of weathering is characterized by solution, decrease of volume, and softening, resulting in physical degeneration. The belt of cementation is characterized by deposition, increase of volume, and induration, resulting in physical coherence.

Chap. 5 treats of minerals. Each of the rock-making minerals is discussed with reference to its occurrence and alterations. The alterations are considered from the physical-chemical point of view. An attempt is made to write chemical equations which represent the transformations, and to calculate the volume relations resulting. It is found that a great number of rock-making minerals undergo two classes of changes, one of which is characteristic of the zone of katamorphism, and the other of which is characteristic of the zone of anamorphism. Perhaps the most important generalization of this chapter is as to the reversibility of reactions in the two opposing zones. This generalization is as follows: The equations which represent the reactions in the zone of katamorphism are reversible in the zone of anamorphism; and, so far as there is expansion of volume and liberation of heat in the upper zone, just so far is there condensation of volume and absorption of heat in the lower zone.

Chap. 6 considers the belt of weathering. The belt of weathering, being the one which is most readily observed, has been treated by many authors. The chapter in this volume on weathering differs from previous discussions in that the phenomena are not considered mainly from the descriptive point of view, the emphasis being given to the classification of the phenomena and their explanation under physical and chemical principles. Also an important feature of this chapter is the consideration of the phenomena of the belt of weathering in relation to the alterations of the other belts of metamorphism.

Chap. 7 treats of the belt of cementation. This belt is defined as extending from the belt of weathering to the bottom of the zone of fracture. The geological results are found to contrast very markedly with those of the belt of weathering. In the latter belt solution is the rule; openings are enlarged; the rocks degenerate. In the belt of cementation, on the other hand, the processes of metamorphism continuously deposit material, the openings are closed, and thus the rocks are consolidated. Each of the cementing substances is considered, and an explanation is offered as to why cementation rather than solution is a general process in this belt.

Chap. 8 treats of the zone of anamorphism. This is the zone in which rock flow occurs. Full explanations of the meaning of rock flow and of the development of such secondary structures as slatiness, schistosity, and gneissosity are offered. Perhaps the most important generalization is that rock flow is mainly accomplished through continuous solution and deposition, that is, by recrystallization of the rocks through the agency of the contained water. But rock flow is partly accomplished by direct mechanical strains. 'At the beginning of the process, during the process, and at the end of the process, the rocks, with the exception of an inappreciable amount, are crystallized solids.

Chap. 9 treats of rocks. A classification of the sedimentary rocks is given, their genesis is discussed, and the series of transformations through which each of the rocks passes is traced out, the resultant rocks being indicated. It was not found possible to give a similar treatment for the igneous rocks.

With the ninth chapter the subject of metamorphism proper closes, but the results contained in these nine chapters have an important bearing upon other parts of physical geology. The remaining chapters consider these relations.

Chap. 10 discusses the relations of metamorphism to stratigraphy. It is shown that in consequence of metamorphism great difficulties are introduced in stratigraphical work. The nature of the difficulties and the manner in which they may be overcome are fully considered.

Chap. 11 treats of the relations of metamorphism to the distribution of the chemical elements. This is perhaps the most daring of the various attempts at generalizing of the treatise. It is shown that as a result of the forces and agents of metamorphism the elements of the original igneous rocks are redistributed, a given element being less abundant in the larger number of sedimentary rocks than in the original rocks, and corresponding with this depletion each of the elements is segregated in one or more formations. An attempt is made to treat the problem of the redistribution of the elements quantitatively. Assumptions are made as to the total mass of the

sediments and of the relative proportions of the more important classes of sediments. Combining these assumptions with the results of chemical analyses, the losses and gains of various formations for each of the important elements of the earth are considered. Many surprising results are reached. For instance, we find the conclusion that to oxidize the ferrous iron of the original rocks to the ferric condition in which most of it occurs in the sedimentary rocks, 35 per cent. of the amount of oxygen in the atmosphere has been required. But still more startling is the conclusion that to oxidize the sulphur and iron of iron sulphides in order to produce the sulphates of the ocean and gypsum deposits, and to transform the iron to the ferric form, required one and one-half times the amount now in the atmosphere.

The final chapter of the book, 12, is upon the relations of metamorphism to ore deposits. It is probable that this chapter will receive more general attention than any other. The material of the other chapters is of a kind which is likely to be of interest to the geologist only, whereas this chapter is of interest to all men concerned in the great mining industry. The chapter on ore deposits occupies 240 pages, and, indeed, might have been named "The Principles of Ore Deposition." From the author's point of view, the majority of ore deposits are produced by metamorphic processes. Having worked out the general principles of metamorphism with reference to rocks, the author found that the application of these principles to ore deposition explained the majority of ore deposits. From his point of view the proper theory of ore deposition consists mainly in bringing the particular phenomena exhibited by ore deposits under the general principles of metamorphism. The chapter contains a new classification of ore deposits, the fundamental divisions of which are the same as those of rocks. Thus ore deposits are divided into three classes—those of sedimentary origin, those of igneous origin, and those of metamorphic origin. Strictly the treatise on metamorphism should, perhaps, have considered only the third class. However, the first and second classes are sufficiently discussed, so that the relations of these ores to those produced by metamorphic processes may be appreciated. The discussion of ore deposits is too elaborate to be summarized in this general statement. But it may be remarked that for the metamorphic ores an attempt is made to trace out the solution, transportation, and precipitation of each of the chief economic metals. Also the alterations and further segregation of metals are fully considered. The conclusion is reached that in many cases an ore deposit does not represent a single segregation, but is the result of repeated segregations by the same general processes which result in the depletion in certain elements of the various rock formations and their segregation elsewhere. In other

words, the principles of the development of ore deposits are the principles of the segregation of those elements which are of importance to man, but which, for the most part, are so rare that they are not included in the discussion in the chapter on the redistribution of chemical elements.

It is not possible in a summary to give any adequate idea of the scope of this treatise on metamorphism. A very broad range of facts, extending far beyond what might at first be regarded as a part of a treatise on metamorphism, is considered from the energy point of view. It is believed that the volume marks a great stride in the reduction of the entire subject of physical geology to order under the principles of physics and chemistry, and points out the way for a treatment of the entire subject from this point of view. K.

The Stone Reefs of Brazil, Their Geological and Geographical Relations, with a Chapter on the Coral Reefs. By JOHN CASPAR BRANNER. (Bulletin of the Museum of Comparative Zoölogy, Cambridge, Mass., 1904.) Pp. 285, 91 plates.

THIS contribution stands almost in a class by itself in that it adds a new variety to the recognized type-formations. While reefs of this class have not been wholly unknown to geologists, they seem to have been regarded rather as individual aberrancies than as expressions of a type dependent on regional conditions and prevalent within the range of those conditions. They have, indeed, been mentioned more or less frequently, but oftenest in such a way as to carry the suggestion that they were coral reefs or some modification of such reefs due to accessions of hardened sand. Their distinctive nature and its peculiarity was recognized by Darwin, Hartt, and a few others, but this comprehensive treatment by Dr. Branner is the first exposition that has brought forth their broader relations and their true significance; indeed, it is the first that has made clear the essential fact that they are not mere aberrant phenomena, due to a fortuitous combination of local conditions, but rather a type of formation, albeit a rare and regional one. While not confined to the coast of Brazil, these sandstone reefs are so limited and peculiar in their distribution, so far as present knowledge goes, as to give special interest to their localization. In the opinion of the author, this regional localization carries genetic significance, and the discussion of this forms a most interesting feature of the book. The peculiarities of these reefs are summarized by the author as follows: